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Estimation of Fall Chum Salmon Abundance On the Tanana and Kantishna Rivers Using Mark Recapture Techniques, 2002

by

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State of Alaska

Frank Murkowski, Governor

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OEO/ADA STATEMENT

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ABSTRACT

Mark-recapture studies on fall chum salmon, *Oncorhynchus keta*, were conducted for the eighth consecutive year on the Tanana River and for the fourth year on the Kantishna River. In the Tanana River, chum salmon were captured and tagged using a fish wheel located on the right bank of the river, approximately 5-km upstream of the Kantishna River mouth, and recaptured in a fish wheel located approximately 76 km upriver on the right bank. In the Kantishna River, chum salmon were captured in a fish wheel on the left bank of the river, approximately 9-km upstream of its confluence with the Tanana River, and recaptured in three fish wheels. Two fish wheels were located approximately 113 km upstream in the Toklat River (one on each bank), and the third fish wheel was located 139 km upstream on the Kantishna River. These studies were conducted during August and September 2002. The final Bailey model abundance estimate for the upper Tanana River was 109,961 (SE = 12,724) chum salmon. The final Bailey abundance estimate for the Kantishna River was 56,665 (SE = 4,122) chum salmon.

KEY WORDS: Tanana River, Kantishna River, chum salmon, *O. keta*, mark-recapture, fish wheel, abundance estimate

INTRODUCTION

The Yukon River drainage is the largest in Alaska (854,700 km^2), comprising nearly one-third the area of the entire state. Five species of anadromous Pacific salmon return to the Yukon River and its tributaries and are utilized in subsistence, personal use, commercial, and sport fisheries. The Tanana River is the largest tributary of the Yukon River. It flows northwest through a broad alluvial valley for approximately 700 km to the Yukon River, draining an area of 115,250 km^2. Chum salmon, *Oncorhynchus keta,* return to the Yukon River in genetically distinct summer and fall runs (Seeb et al. 1995). Summer chum salmon begin to enter the Yukon River in early May, and fall chum salmon enter in mid-July. Fall chum salmon migration typically peaks around mid-September in the Tanana River and continues into early October. Spawning occurs from October through November, primarily in areas where upwelling ground water prevents freezing. Fall chum salmon are larger on average than summer chum salmon, have higher oil content, and are important to subsistence, personal use, and commercial fisheries within the upper Yukon and Tanana Rivers.

The Tanana River drainage is a major producer of Yukon River fall chum salmon and contributes to various inriver fisheries. The most recent 5-year (1996-2000) average total harvest of fall chum salmon in the Tanana River is approximately 21,000 fish, which is approximately 16% of the entire average catch of the Yukon River drainage for those years (Vania et al. 2002). However, this average includes the years 1997, during which the run to the Tanana River was particularly weak, and 1998, 2000 and 2001, years in which regulatory restrictions and closures decreased normal harvest. Additionally, this harvest does not include those fish taken downstream of the Tanana River in Districts 1-4 and Subdistrict 5-A.

The Alaska Department of Fish and Game (ADF&G) has management responsibility for fisheries in the Alaska portion of the Yukon River drainage. For management purposes, the drainage is divided into 13 districts and subdistricts. The Tanana River (District 6) is divided into Subdistricts, 6-A, 6-B, and 6-C and the area upstream of Subdistrict 6-C to the headwaters known as the upper Tanana River (Figure 1). For the purpose of the Tanana tagging project, all areas upstream of Subdistrict 6-A are considered the upper Tanana River because the location of tagging projects in relation to the major fall chum salmon spawning grounds is upstream of both Subdistricts 6-B and 6-C. Tanana River summer and fall chum salmon are managed as distinct stocks and are divided into summer and fall seasons according to the established date of 16 August in the Upper Yukon Area. Although some overlap in migration does occur, this date has been selected for management purposes based on average historical run timing.

Subsistence and personal use fisheries occur within District 6 and are usually open for two 42-hour periods per week, with the exception of the "Old Minto" area where subsistence fishing is allowed five days a week. Commercial fishing occurs on the Tanana River in Subdistricts 6-B and 6-C by emergency order for not more than 42-hours fishing per week (Subdistrict 6-A is limited to one 24 hour period per week). The Tanana River commercial guideline harvest range is 2,750 to 20,500 fall chum salmon, but the harvest level may be exceeded if assessment of run size indicates both escapement goals and subsistence needs will be met. In 2002, however, no commercial fishery was permitted because of a weak return of fall chum salmon. In addition,

subsistence fishing on the Tanana River (Subdistricts 6-A and 6-B) was closed from 16 August until 13 September, at which time it was reopened for a directed coho salmon, *O. kisutch,* fishery, and live boxes or chutes were used to release chum salmon for a single 24-hour period. The full subsistence schedule was reestablished in District 6 on 16 September for two 42-hour periods per week. Personal use fishing was opened for two 42-hour periods per week with gear restrictions that included use of live chute and dip nets from which all chum salmon had to be released.

Aside from information provided by this project, management decisions for the Tanana River are partially based on catch-per-unit-effort (CPUE) data from department-contracted "test" fish wheels and historical fishery performance data. Information obtained from these sources is used inseason to qualitatively assess run strength. However, these data have limitations, and managers are unable to use them to assess absolute run strength. Fish wheels are susceptible to inconsistencies in efficiency, both within and among years. Although attempts are made to operate test fish wheels at the same location each year, conditions at a given location may change annually in relation to water level, current and channel configurations. The Tanana River is dynamic, and these factors are known to fluctuate widely. This variability reduces the reliability of test fish wheel data for making inseason management decisions.

Fishery managers rely on aerial and ground surveys to assess the escapement into select fall chum salmon spawning areas within the Tanana River drainage. ADF&G recently established biological escapement goal (BEG) ranges for fall chum salmon: 15,000 to 33,000 in the Toklat River, a tributary of the Kantishna River; 6,000 to 13,000 in the Delta River, a tributary of the Tanana River; and 61,000 to 136,000 for the entire Tanana River (Eggers 2001). Intensive annual ground surveys are conducted on spawning grounds in each of these rivers to estimate salmon escapement. Because of its importance as a fall chum salmon spawning tributary (Barton 1997), a sonar project using Bendix sonar gear was operated in the Toklat River from 1994 to 1996 to develop a better assessment of escapement. A main river sonar project located at river mile 123 near the village of Pilot Station estimates passage of all salmon species in the lower Yukon River (McIntosh in prep). Additional projects estimate spawning escapement of fall chum salmon in the upper Yukon River tributaries, including the Chandalar, Sheenjek, and Fishing Branch Rivers and the upper Yukon River (JTC 2002). Before 1995, however, no program estimated total fall chum salmon population size in the Tanana River. While estimates provided by the main river sonar project are valuable for the drainage as a whole, operational aspects and the cost of combining acoustic estimates of abundance with stock identification techniques complicate determination of the strength of the Tanana River fall chum salmon component.

In 1996, the U.S. Fish and Wildlife Service (USFWS) implemented a mark-recapture project located at Rampart Rapids on the Yukon River, 58 km upriver of the Tanana-Yukon River confluence, to estimate population size of fall chum salmon in the Yukon River drainage upstream of the village of Rampart (Gordon et al. 1998). Results from the projects stated above have the potential to verify Tanana River population estimates. Although inseason assessment of drainage wide Yukon River fall chum salmon run strength is important, it may not accurately reflect the strength of the Tanana River run component in a given year because of differences in run strength and run timing between Tanana and non-Tanana stocks. Consequently, a reliable inseason estimate of run strength for the Tanana River is useful for management.

The Kantishna River drainage is known to contain at least one major fall chum salmon stock that spawns in the Toklat River tributary. In 1999 the scope of the project was expanded through the Western Alaska Salmon Fisheries Disaster Mitigation Research Plan (WADG) to estimate the abundance of both upper Tanana and Kantishna River fall chum salmon. In addition to one tagging and one recovery fish wheel operated in the mainstem Tanana River, one tagging fish wheel was operated in the lower Kantishna River, and two recovery fish wheels were operated in the Toklat River (Cleary and Bromaghin 2001). In 1999, a large disparity between the Kantishna River fall chum salmon population estimate and the upper Toklat River expanded ground survey estimate became evident. This disparity led to speculation that a larger proportion of chum salmon migrated to the upper Kantishna River (i.e., upstream of the Toklat River) than was previously thought. In an effort to understand the relative abundance and timing of upper Kantishna River fall chum salmon stocks and to satisfy the closed population premise of the study, an additional recovery fish wheel has operated in the upper Kantishna River since 2000 (Cleary and Hamazaki 2002). By operating recovery fish wheels in each tributary, the Kantishna River abundance estimate includes both the Toklat and upper Kantishna River chum salmon components.

Objectives for the 2002 season were to: Provide management staff with both inseason and postseason abundance estimates of fall chum salmon in the upper Tanana and Kantishna Rivers, and estimate migration rates for fall chum salmon. In addition, estimate run timing of fall chum salmon to the Delta River, Tanana River drainage, Toklat River, and to the upper Kantishna River.

METHODS

Sampling

In 2002, one tagging fish wheel and one recovery fish wheel were operated in the Tanana River. One tagging fish wheel was operated in the Kantishna River, two recovery fish wheels were operated in the Toklat River, and one recovery fish wheel was operated in the upper Kantishna River. In the Tanana River, a new three-basket wheel was operated to increase the number of deployed tags. The Bailey population model (Bailey 1952) was used to generate Tanana and Kantishna River population estimates both inseason and postseason in 2002.

The Tanana and Kantishna River mark-recapture studies utilized tag deployment and recovery fish wheels. In the Tanana River, one tagging fish wheel was located 9 km upstream of the Kantishna River mouth, and one recovery fish wheel was located 76 km upstream of the tagging sites and downstream from the Nenana River (Figure 2). These two locations were selected because of the absence of main tributaries between the two sites (with the exception of the Tolovana River), which satisfies a 'closed population' (i.e., no immigration, emigration, mortality) assumption, the main premise of the mark-recapture study.

Because the Kantishna River drainage branches 58 km upstream of the tagging site, recovery sites were located in both the Toklat and upper Kantishna River branches. The Toklat River recovery site is located 113 km upstream of the Kantishna River tagging fish wheel where two tag recovery fish wheels were operated on the left and right banks of the river. The upper Kantishna River recovery fish wheel was operated 139 km upstream of the Kantishna River tagging fish wheel on the right bank of the river. By operating recovery fish wheels in each tributary of the drainages, the closed population assumption was satisfied. At the recovery fish wheel locations, equal probability of capture could be examined by determining the marked to unmarked ratio at each site.

Tag Deployment

The Tanana and Kantishna River tagging fish wheels are owned and operated by private contractors. In the Tanana River, the fish wheel was positioned on the right bank at approximately 8 km upstream from the mouth of the Kantishna River and within 100 meters of the 1995-2001 fish wheel locations (Figure 2). This site has a fairly stable river channel with a moderate to slow current that provides a relatively consistent location for fish wheel operation. In the Kantishna River, a tagging fish wheel funded by the Bering Sea Fishermen's Association (BSFA) was positioned on the left bank at approximately 9 km above the mouth of the river. Both tagging fish wheels were equipped with baskets that measured 2.5-3 m in width with a dip capacity of approximately 4 m and a live box that measured 2.4 x 1.2 x 0.6 m (length, width, depth) and was constructed of spruce poles and one-half inch plywood and submerged on the offshore side of the fish wheel. Fish leads, ranging from 2 to 5 meters in length, were installed shoreward as needed, depending on the distance of the fish wheel from the riverbank. Contractors examined their respective fish wheels at least once a day to determine overall operating efficiency, to check for damage such as tears, rips or holes in the baskets or live-box, and to remove any accumulated debris. To maximize operating efficiency, the fish wheels were occasionally adjusted by moving the fish wheel laterally, raising or lowering the axle to allow baskets to turn close to the bottom, lengthening or shortening onshore fish leads, and adding or removing basket paddle boards to accommodate changes in river current.

Unless interrupted by debris accumulation or fish wheel relocation, the two tag deployment fish wheels were operated 24 hours per day. Tagging fish wheels operated from 16 August until 27 September on the Tanana River and from 16 August to 24 September on the Kantishna River. At each location a daily 12-hour tag deployment schedule was maintained from 08:00 to 20:00. A 24-hour catch-day was designated as 08:00 to 08:00 the following day. The sampling crew checked the live-box at each fish wheel in approximate 4-hour intervals (07:30, 12:00, 16:00 and 19:30). Using a dip net, all chum salmon in the live-box were individually transferred to a sampling tub. Fish were tagged with a 30 cm, hollow core, individually numbered spaghetti tag (Floy Tag and Manufacturing Inc., Seattle, WA)[2] that was inserted with a 16 cm applicator needle into the dorsal musculature behind to the dorsal fin and secured with an overhand knot tied close to the body. Orange tags were used on the Tanana River and pink tags on the Kantishna River.

[2] Mention of trade names does not constitute endorsement by ADF&G.

The right pelvic fin was partially clipped as a secondary mark. Data recorded were: (1) length, measured from mid-eye to fork-of-tail (MEFT) at nearest five cm; (2) sex, determined by external physical appearance; (3) condition, determined by external physical aberrations subjectively judged as having the potential to affect survival or migration; and (4) exterior color, graded by light or dark. Because of the possible effect on the abundance estimate, chum salmon that had severe wounds (bleeding, large gashes, head injuries, fungus, etc.) were not tagged. Fish caught between 08:00 and 20:00 were categorized as day-fish, while fish caught between 20:00 and 08:00 and held in the live-box for up to 12 hours were categorized as night-fish. Total handling time per fish was approximately one minute. All chinook salmon, *O. tshawytsha,* and coho salmon were enumerated by sex and released, while other species were identified, enumerated, and released.

To monitor fish wheel efficiency, fish wheel revolutions occurring over 15-minute intervals were recorded daily. In addition, meteorological data, water temperature and level were recorded once a day at the tagging camp at approximately 10:00. Measurements that were collected were entered into a computer spreadsheet after each sampling session. A data summary for the previous 24-hour tagging day was reported daily to the ADF&G Fairbanks office via cellular or satellite telephone.

Tag Recovery

Recovery fish wheels in the upper Tanana River and upper Kantishna River were owned and operated by private contractors, while the Toklat River recovery fish wheels were operated by ADF&G. In the upper Tanana River, one fish wheel was positioned on the right bank approximately 76 km upstream from the tagging fish wheel. The Tanana River recovery fish wheel also served as an ADF&G management test fish wheel and was operated during both the summer and fall chum salmon migrations. Two fish wheels were positioned on each bank of the Toklat River 113 km upstream, and one fish wheel was located on the right bank of the Kantishna River 139 km upstream (Figure 2). Design, size and construction materials used in the recovery fish wheels and live-boxes were similar to those of the tag deployment fish wheels, except the right bank fish wheel on the Toklat River had a new raft made of plastic foam-filled floats. Primary reasons for using the plastic floats were to replace old water-logged rafts, for ease in moving the fish wheel to a better location or storage site, and to resolve the limitations of the camp outboard motor which had insufficient power to push the fish wheels upstream in high water velocity.

On the Tanana River, the recovery fish wheel began operation on 16 August and continued through 4 October. On the Toklat River, recovery fish wheel operations began on 22 and 26 August on the left and right bank respectively and ended on September 26 and 28 on the left and right bank respectively. On the Upper Kantishna River, recovery fish wheel operation began on 16 August and ended on 6 October. Like tag deployment fish wheels, recovery fish wheels were inspected daily and adjusted as necessary. All chum salmon were enumerated by sex and released. The color and identification numbers of all recaptured tags were recorded. All chum salmon not bearing tags were examined for the secondary mark, a right pelvic fin clip. Additionally, all chinook and coho salmon were enumerated by sex, while other species were

enumerated daily. The ADF&G office in Fairbanks was contacted daily via satellite or cellular telephone to report summary data for the previous 24-hour catch. ADF&G personnel recovered tags on the Toklat and Delta Rivers and on Bluff Cabin Slough.

Data Analysis

Abundance Estimation

Tag deployment and tag recovery data were entered daily into a spreadsheet in the Fairbanks office. Inseason abundance estimates were available in a spreadsheet to provide management staff with a preliminary run size for fall chum salmon. Fishery managers used inseason estimates, along with other run assessment data, for decision-making. Inseason estimates were produced without adjusting for assumptions required to make an accurate and unbiased estimate. For the final postseason estimate, all the assumptions were tested and adjustments were made to provide unbiased estimates.

Bailey's modified Peterson estimate was employed to estimate the total fall chum salmon run size for the Tanana and Kantishna Rivers.

Bailey's estimation equation is:

$$\hat{N} = \frac{(C+1)(M)}{R+1} \tag{1}$$

$$V\left[\hat{N}\right] \cong \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)} \tag{2}$$

Where:

$\hat{N}$ = Total run estimate.

M = The number of fish tagged and released at the tagging fish wheels.

C = The number of fish caught at the recovery fish wheels.

R = The number of tagged fish recaptured at the recovery fish wheels.

Data Reduction and Adjustment

Numbers of marked and unmarked fish were adjusted using the distribution of travel times for marked fish. This adjustment was necessary because some unmarked fish were between tagging and recovery fish wheels when the study began (16-24 August for the Tanana River, 16-27 August for the Kantishna and Toklat Rivers), and some marked fish would not reach the recovery fish wheel when the study ended. For each day the number of unmarked fish was

multiplied by the appropriate cumulative proportion, which resulted in a final vector of the daily number of unmarked fish captured in the recovery fish wheels (Tables 1-2). Distribution of travel times of marked fish was assumed to be an accurate representation of the distribution of travel times of unmarked fish. Travel times of marked fish could differ from that of unmarked fish because of possible stress from capture and tagging.

Migration Rate

Migration rate between the tagging and recovery fish wheels was calculated as:

$$\hat{M} = \frac{RD}{D} \tag{3}$$

Where:

RD = Distance between a tagging fish wheel and recovery fish wheel (76 km on the Tanana River, 113 km from the Kantishna River to the Toklat River recovery fish wheels, and 139 km from the Kantishna River tagging fish wheel to the upper Kantishna River recovery fish wheel).

D = Number of days taken for a tagged fish to be recaptured at a recovery fish wheel.

Diagnostic Statistical Tests

Bailey's closed population model requires the following assumptions: (1) no immigration, emigration, and mortality between the tagging and recovery sites; (2) all marked fish mix completely with unmarked fish; and (3) all fish have an equal probability of recapture. These conditions were examined before estimating abundance.

While mortality induced by tagging and handling is unknown, a mortality rate of 5% has been used in all years of the study. This number is derived from the radio-tag study in which 5.2% of radio-tagged fall chum salmon in the Tanana River did not migrate upstream (Barton 1992).

To examine the assumption of complete mixture of marked and unmarked fish, the following were tested: (1) equal travel time from release to recapture sites between day fish and night fish; (2) equal recapture rate (i.e., marked-unmarked ratio) among recovery fish wheels, (i.e. between left and right bank fish wheels, between the Toklat and Kantishna River recovery sites); and (3) across time. Equality of travel time between day and night fish was examined using the Kolmogorov-Smirnov test. Equality of recapture rates was examined using Chi-square tests. Finally, to examine the assumption that all fish have an equal probability of recapture, logistic regression (Hosmer and Lemeshow 1989) was utilized in which recapture events (i.e. 1 = recaptured, 0 = not recaptured) were regressed with sex and size.

When the equal recapture rate for size or sex was violated (logistic regression test), the data were stratified for size and sex, and estimation was conducted separately for each strata. Whenever the

complete mixture assumption was violated, Darroch's (1961) estimation methods were used. However, Darroch's methods employ a maximum-likelihood estimation technique that requires abundant recapture data to stabilize the estimation. Thus, when there was insufficient recapture data, even though the complete mixture assumption was violated, Darroch's (1961) method was not used.

Stock Timing

ADF&G personnel conducted ground surveys of the Delta and Toklat Rivers. Escapement counts consisted of the number of live and dead chum and coho salmon. On the Delta River, 7 replicate surveys were conducted from 10 October through 2 December. On the Toklat River, one intensive survey was conducted of the fall chum spawning area 14 through 16 October. Approximately half of the spawning area was surveyed by foot, while the remainder was completed during an aerial survey. USGS and ADF&G personnel conducted two ground surveys in November during the peak of spawning activity on Bluff Cabin Slough on the upper Tanana River. When possible, tags were retrieved at these locations.

RESULTS

Sampling

Tag Deployment

Tagging fish wheels operated from 16 August until 27 September on the Tanana River and from 16 August to 24 September on the Kantishna River. At the Tanana River tagging fish wheel, a total of 2,616 fall chum salmon were tagged (Appendix A) of which 1,223 were males and 1,393 were females. The peak chum salmon CPUE of 17.04 fish/hour occurred on 12 September on the Tanana River (Figure 3 and Figure 4, upper panel). A total of 396 chum salmon were not tagged due to death in the live-box, escape, or injuries that might affect swimming ability. At the Kantishna River tagging fish wheel, 3,159 chum salmon were tagged (Appendix B) of which 1,899 were males and 1,260 were females. The peak chum salmon catch of 13.50 fish/hour occurred on 13 September (Figure 3, lower panel). A total of 962 (23%) chum salmon were not tagged for the same reasons given above. As in 2001, extra measures were taken to screen out fish with debilitating injuries that might affect their migration to the recovery wheel site and thus affect the abundance estimate.

Tag Recovery

At the Tanana River recovery fish wheel, a total of 3,262 chum salmon were examined for marks of which 2.8% (71) were tagged (Appendix C). In the Toklat River recovery fish wheels, 3,175 chum salmon were examined of which 5.2% (167) were tagged (Appendix D). Four chum salmon, not included in the total number of tags recovered, were recaptured twice. In the upper Kantishna River recovery fish wheels, 260 chum salmon were examined of which 5.4% (14) were tagged (Appendix E). A total of 652 chum salmon tags were recaptured from various sources. One hundred tags were recovered from eight foot surveys on the Delta River, 28 tags were recovered from two surveys on Bluff Cabin Slough while collecting egg samples for evaluation of 3 November earthquake effects, and 252 tags (including four tags that were deployed from the Tanana River, one tag that was deployed in 1999, two in 2000 and six in 2001) were recovered from foot surveys on the Toklat River springs conducted 14 through 16 October. In addition, one tag was recovered from Russian Mission, eleven from an area near the Tolovana Lodge (Tanana River) and seven from Nenana (Table 5).

As in 2001, water levels on the Tanana and Kantishna Rivers were above average for most of the project, which may have affected fish wheel efficiency (Figure 5). The catch-per-unit-effort (CPUE) at the Tanana River tagging fish wheel was low until 8 September, when it began to increase appreciably. This has been the precedent for all years of the project.

Data Analysis

Abundance Estimate

Inseason abundance estimates with confidence intervals were generated daily and provided to management staff on the local server (Figure 6). Final abundance estimates were adjusted using the cumulative proportion of travel time between the tag deployment and recovery wheels (Tables 1 and 2), the adjusted number of tag releases, and the adjusted number of unmarked catch (Tables 3 and 4). The final abundance estimate using the Bailey model was 109,961 (SE 12,724) fall chum salmon for the Tanana River with 95% confidence interval (85,022; 134,900) and coefficient of variation (CV) of approximately 0.12. For the Kantishna River, the final abundance estimate was 56,665 (SE 4,122) fall chum salmon with 95% confidence interval (48,587; 64,743) and a CV of approximately 0.07 (Tables 6, 7 and 8).

Migration Rate

Mean migration rates for the Tanana River were 28 km/day (n = 22) for day-tagged (day) fish and 29 km/day (n = 47) for night-tagged (night) fish for a combined mean of 29 km/day. This migration rate is similar to the average migration rates for 1998-2001. The average migration rate was three days from the tagging fish wheel to the recovery fish wheel, and the maximum migration rate was 9 days (Table 9).

Mean migration rates between the Kantishna River tagging fish wheel and the Toklat River recovery fish wheels were 24 km/day (n = 84) for day fish and 27 km/day (n = 81) for night fish for a combined mean of 26 km/day, excluding one fish with an extreme migration rate. The migration rate between the Kantishna River tagging fish wheel and the upper Kantishna River recovery fish wheel was 21 km/day (n = 10) for day and night fish (n = 4). The average migration rate was five days from the tagging to recovery fish wheels on the Toklat River, and the maximum migration rate was 20 days, which was not included in estimating the average migration. Average migration rate was five days between the Kantishna River tagging fish wheel and the upper Kantishna recovery fish wheel (Table 9).

Diagnostic Statistical Tests

Mean migration rate for day-tagged fish was similar to the rate for night-tagged fish in the Tanana River (28 and 29 km/day, KS test D = 0.33, df 16, P>0.05), while it was not similar in the Kantishna/Toklat Rivers (24 and 27 km/day, KS test D = 0.27, df 24, P>0.05) for day and night fish respectively. Logistic regression tests were not conducted because of the low tag recovery rates.

Chi-square tests indicated a significant difference in recapture rates between left and right bank fish wheels on the Toklat River (Chi-square 6.990, df 1, P = 0.008), but not for day and night tagged fish on the Tanana River (Chi-square 0.535, df 1, P = 0.456), or for day and night tagged fish on the Toklat River (Chi-square 0.882, df 1, P = 0.348) or between the Toklat and Kantishna River recapture sites (Chi-square 0.462, df 1, P = 0.497). In addition, chi square tests showed no significant difference over ten-day periods in the Tanana River (Chi-square = 3.988, df 3, P = 0.263) or the Toklat River (Chi-square = 2.607, df 3, P = 0.456). A Chi square test was not performed for the Kantishna River tag recovery fish wheel because of the low number of tag recoveries. Goodness-of-fit test of multiple logistic regression models with predictor variables of size and sex were performed for the Tanana and Kantishna Rivers, but they failed to provide reliable results due to low recapture rates.

No commercial chum salmon fishery occurred in Subdistricts 6-B and 6-C in 2002, and the preliminary subsistence harvest estimate for this area was approximately 1,654 fall chum salmon (Brase in prep.).

Stock Timing

One hundred chum salmon tags were recovered during surveys of spawning grounds in the Delta River conducted between 17 October and 3 December 2002. The median tag deployment date for tags recovered in the Delta River was 13 September. Tagging dates ranged from 24 August through 28 September, and 86% of the tags recovered were deployed after 10 September. Median tag deployment dates for tags recovered in the Delta River were 14 September in 1995-1997, 27 September in 1998, 20 September in 1999, 30 August in 2000, and 8 September in 2001. The median tag deployment date for tags recovered in the Toklat River was 19 September, and the tag deployment dates ranged from 25 August to 23 September. Median tag deployment dates for tags recovered in the Toklat River were 15 September in 1999 and 11 September in 2000 and 2001.

DISCUSSION

Tanana River mean migration rates for tagged fish were similar for day and night fish and ranged from 28 km/day (n = 22) and 29 km/day (n = 47) respectively. Like the results from previous years of this study, no correlation was detected between holding time and reduced migration rates (Table 9). Thus, holding fish in live boxes does not appear to have any effects on migration rates.

Kantishna River mean migration rates for tagged fish, 24 km/day (n = 84) and 27 km/day (n = 81) for day-tagged and night-tagged fish respectively, were unlike migration rates on the Tanana River, and the KS test indicated a significant difference between these two groups. However, like the Tanana River, night-tagged migration rates were greater than day-tagged migration rates, which suggest that holding time does not reduce migration rates. During 1999–2001, night-tagged migration rates were greater on the Kantishna River (Table 9).

The 2002 Tanana River abundance estimate of 109,961 fall chum salmon (similar to the 1999 estimate of 97,843 fish), while average, is the greatest escapement since 1997 (Table 8, Figure 7). The ADF&G test fish wheel located on the left bank of the Yukon River near the village of Tanana captured 9,133 fall chum salmon, which is approximately 9.2% greater than 1994-2001 average annual catch. Additionally, the 2002 spawning ground surveys in the Toklat River revealed an escapement of approximately 28,500 fall chum salmon (Borba personal communication) which, although below the minimum escapement objective of 33,000 fish (BOF regulation 5AAC 01.248), is the greatest escapement since 1995. This is significant given the poor escapements in the 1997 and 1998 brood years. However, poor escapement does not necessarily result in poor return of adults. For example, the 1995 escapement on the Toklat River was 54,513 (Vania et al. 2002), yet the poor returns to the Toklat River in both 1999 and 2000 represent the four and five year old fish from the 1995 brood year. Other indications of exceptional run strength (compared to recent years) in the Tanana River in 2002 include the preliminary Delta River escapement (based on foot survey counts) of approximately 12,000 fall chum salmon, which is within the escapement range of 6,000 to 13,000 (Borba, personal

communication). Conversely, Yukon River fall chum run strength was poor as indicated by the 2002 preliminary estimate of approximately 359,565 fall chum salmon at Pilot Station sonar. This estimate is the second lowest on record for the project. For comparison, the preliminary historical average (1995-2001) estimate at the Yukon River Sonar project is 511,507 (JTC 2002).

Water levels on the Tanana and Kantishna River were above average for most of the season. High river discharge may have had an effect on CPUE by forcing migrating chum salmon to travel along the bank and consequently make them more susceptible to capture. A new three-basket fish wheel was operated in the Tanana River that may have contributed to an increased CPUE compared to other years. As expected, fish wheel revolutions did increase as water velocity increased, however regression analysis indicated no correlation between wheel revolutions or water velocity on CPUE in the Tanana River.

Although the Tanana tag deployment wheel had a high CPUE this season, the same was true for the Tanana River recovery wheel which resulted in a low marked proportion at the tag recovery wheel. The Kantishna River tag deployment wheel had the greatest CPUE since inception of the project, and as a result a large number of tags were deployed. On the Toklat River, despite a late start, the large number of tags recaptured at the recovery wheels resulted in a small range in the confidence interval compared to the Tanana River.

The key to operating a fish wheel efficiently is to maintain adjustments according to water level. Adjustments include raising or lowering the baskets to compensate for water depth, adjusting the fish wheel with respect to distance from shore, and moving the fish wheel up or down the riverbank. The right bank fish wheel was moved without difficulty because of its new raft design (plastic foam filled floats). This design may have led to an increased CPUE compared to the left bank fish wheel which is constructed of a heavier log raft and may not have been operated in the best location. For example, the left and right bank fish wheel catches, although identical in 2000, were lower in the right bank in 1999 and 2001. This discrepancy indicates the new right bank fish wheel raft used in 2002 may have helped to increase the CPUE at this site.

RECOMMENDATIONS

Because physiological stress effects have been documented to occur from fish wheel capture and tagging (Cleary 2003.), additional efforts should be made to minimize injury to captured salmon by modifying fish wheels to include padding on the fish wheel baskets and live boxes. Although migration rates do not appear to be affected by holding, no method exists to estimate migration rates after the second capture event in the Toklat River. However, among the tags recovered from the Toklat Springs, approximately 60% were from day fish. Although a greater percentage of tags recovered from fish that spent less time in the live box may be a chance occurrence, this observation suggests fish held longer (night fish) may have a lower probability of reaching the spawning grounds. However, more day tags were deployed (51%) compared to night tags, so the number of day tags recovered may be due to the number of tags deployed rather than mortality caused by holding.

High catch rates and live box densities caused mortalities at the Tanana recovery wheel this season during the peak of the fall chum salmon run. Fish wheel hours of operation were reduced to avoid additional fall chum and coho salmon mortalities. To prevent mortalities, a video system should be installed at this location to allow captured salmon to be immediately returned to the water. Video monitoring of fish wheel catches has been used successfully on the Yukon River for several years (Fliris 2001). Video methods can be used for the mark recapture phase of the study (fall season) and during the summer season for run strength assessment of chinook and chum salmon. As tag retention is critical to abundance estimation, an intensive effort to inspect all fall chum salmon for tag losses by examining fish for a secondary mark should be stressed to all the operators of recovery fish wheels.

Interior Alaska experienced a large earthquake on 3 November after most fall chum salmon had completed spawning in the Toklat River. The potential effect of an earthquake on developing chum salmon could include mechanical kills caused by shifting of substrates or siltation (Noerenberg and Ossiander 1964). This potential source of mortality justifies collecting pre-emergent fry samples to estimate egg to fry survival on the Toklat River. Aside from collecting data to examine possible egg mortality as a result of the earthquake, this study, if completed on a yearly basis, would answer fundamental life history questions by obtaining an annual index of egg to fry survival on the Toklat River. Comparisons between spawning ground conditions (depth and temperature monitored using data loggers) and egg mortality could be used to determine if egg mortality is correlated with adult return.

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Table 1. Counts and cumulative proportions of travel time between tag deployment and recovery fish wheels on the Tanana River used in the data reduction for the Bailey estimator, 2002.

Travel Time (days)	Day Tag Count	Day Tag Cumulative Proportion	Night Tag Count	Night Tag Cumulative Proportion	Combined Count	Combined Cumulative Proportion
0	0	0.00	0	0.00	0	0.00
1	17	0.36	10	0.45	27	0.39
2	18	0.74	7	0.77	25	0.75
3	8	0.91	4	0.95	12	0.93
4	3	0.98	0	0.95	3	0.97
5	0	0.98	0	0.95	0	0.97
6	1	1.00	0	0.95	1	0.99
7	0	1.00	0	0.95	0	0.99
8	0	1.00	1	1.00	1	1.00
Total	47		22		69	

Table 2. Counts and cumulative proportions of travel time between the tag deployment fish wheel on the Kantishna River and recovery fish wheels on the Toklat and Kantishna Rivers used in the data reduction for the Bailey estimator, 2002.

Travel Time (days)	Day Tag Count	Day Tag Cumulative Proportion	Night Tag Count	Night Tag Cumulative Proportion	Combined Count	Combined Cumulative Proportion
1	0	0.00	0	0.00	0	0.00
2	0	0.00	1	0.01	1	0.01
3	4	0.05	17	0.22	21	0.13
4	29	0.39	28	0.56	57	0.48
5	29	0.74	22	0.83	51	0.78
6	14	0.90	6	0.90	20	0.90
7	5	0.96	3	0.94	8	0.95
8	0	0.96	1	0.95	1	0.96
9	3	1.00	3	0.99	6	0.99
10	0	1.00	0	0.99	0	0.99
11	0	1.00	0	0.99	0	0.99
12	0	1.00	1	1.00	1	1.00
Total	84		82		166	

Table 3. Observed and adjusted number of releases at the tag deployment fish wheel and observed and adjusted number of unmarked catches at the recovery fish wheel used in the Bailey model to estimate the abundance of fall chum salmon in the Tanana River, 2002.

Date	Tags Released	Estimated Proportion at Recovery Wheels	Adjusted Tags Released	Unmarked Catch	Estimated Proportion at Tagging Wheel	Adjusted Unmarked Catch	Adjusted Cumulative Tags Released	Cumulative Catch Unmarked
8/16	2	0.95	2	9	0.00	0	2	0
8/17	6	0.95	6	7	0.39	3	8	3
8/18	3	0.95	3	10	0.75	8	10	10
8/19	5	0.95	5	1	0.93	1	15	11
8/20	0	0.95	0	0	0.97	0	15	11
8/21	0	0.95	0	0	0.97	0	15	11
8/22	4	0.95	4	0	0.99	0	19	11
8/23	16	0.95	15	1	0.99	1	34	12
8/24	24	0.95	23	0	1.00	0	57	12
8/25	41	0.95	39	1	1.00	1	96	13
8/26	27	0.95	26	2	1.00	2	122	15
8/27	31	0.95	29	1	1.00	1	151	16
8/28	24	0.95	23	5	1.00	5	174	21
8/29	27	0.95	26	7	1.00	7	200	28
8/30	10	0.95	10	9	1.00	9	209	37
8/31	17	0.95	16	12	1.00	12	225	49
9/1	8	0.95	8	22	1.00	22	233	71
9/2	6	0.95	6	22	1.00	22	238	93
9/3	14	0.95	13	38	1.00	38	252	131
9/4	18	0.95	17	40	1.00	40	269	171
9/5	18	0.95	17	116	1.00	116	286	287
9/6	76	0.95	72	103	1.00	103	358	390
9/7	59	0.95	56	127	1.00	127	414	517
9/8	74	0.95	70	172	1.00	172	485	689
9/9	70	0.95	67	147	1.00	147	551	836
9/10	97	0.95	92	194	1.00	194	643	1,030
9/11	264	0.95	251	254	1.00	254	894	1,284
9/12	363	0.95	345	256	1.00	256	1,239	1,540
9/13	288	0.95	274	302	1.00	302	1,512	1,842
9/14	190	0.95	181	115	1.00	115	1,693	1,957
9/15	167	0.95	159	152	1.00	152	1,852	2,109
9/16	92	0.95	87	133	1.00	133	1,939	2,242
9/17	81	0.95	77	105	1.00	105	2,016	2,347
9/18	54	0.95	51	101	1.00	101	2,067	2,448
9/19	80	0.95	76	58	1.00	58	2,143	2,506
9/20	81	0.95	77	40	1.00	40	2,220	2,546
9/21	69	0.95	66	73	1.00	73	2,286	2,619
9/22	60	0.95	57	77	1.00	77	2,343	2,696
9/23	38	0.95	36	63	1.00	63	2,379	2,759
9/24	31	0.95	29	53	1.00	53	2,408	2,812
9/25	16	0.95	15	62	1.00	62	2,423	2,874
9/26	30	0.94	28	50	1.00	50	2,452	2,924
9/27	35	0.94	33	55	1.00	55	2,484	2,979
9/28	0	0.92	0	43	1.00	43	2,484	3,022
9/29	0	0.92	0	31	1.00	31	2,484	3,053
9/30	0	0.88	0	45	1.00	45	2,484	3,098
10/1	0	0.72	0	27	1.00	27	2,484	3,125
10/2	0	0.72	0	30	1.00	30	2,484	3,155
10/3	0	0.37	0	16	1.00	16	2,484	3,171
10/4	0	0.00	0	4	1.00	4	2,484	3,175

Table 4. Observed and adjusted number of releases at the tag deployment fish wheel and observed and adjusted number of unmarked catches at the recovery fish wheel used in the Bailey model to estimate the abundance of fall chum salmon in the Kantishna River, 2002.

Date	Tags Released	Estimated Proportion at Recovery Wheels	Adjusted Tags Released	Unmarked Catch	Estimated Proportion at Tagging Wheel	Adjusted Unmarked Catch	Adjusted Cumulative Tags Released	Cumulative Catch Unmarked
8/16	8	0.95	8	3	0.00	0	8	0
8/17	12	0.95	11	1	0.01	0	19	0
8/18	16	0.95	15	0	0.13	0	34	0
8/19	9	0.95	9	0	0.48	0	43	0
8/20	4	0.95	4	0	0.78	0	47	0
8/21	7	0.95	7	2	0.90	2	53	2
8/22	14	0.95	13	2	0.95	2	67	4
8/23	16	0.95	15	2	0.96	2	82	6
8/24	23	0.95	22	5	0.99	5	104	11
8/25	14	0.95	13	2	0.99	2	117	13
8/26	22	0.95	21	1	0.99	1	138	14
8/27	19	0.95	18	12	1.00	12	156	26
8/28	22	0.95	21	15	1.00	15	177	41
8/29	18	0.95	17	11	1.00	11	194	52
8/30	21	0.95	20	16	1.00	16	214	68
8/31	27	0.95	26	13	1.00	13	239	81
9/1	26	0.95	25	31	1.00	31	264	112
9/2	14	0.95	13	17	1.00	17	277	129
9/3	35	0.95	33	26	1.00	26	311	155
9/4	64	0.95	61	35	1.00	35	371	190
9/5	22	0.95	21	52	1.00	52	392	242
9/6	104	0.95	99	49	1.00	49	491	291
9/7	161	0.95	153	36	1.00	36	644	327
9/8	158	0.95	150	49	1.00	49	794	376
9/9	163	0.95	155	51	1.00	51	949	427
9/10	207	0.95	197	48	1.00	48	1,146	475
9/11	229	0.95	218	96	1.00	96	1,363	571
9/12	228	0.95	217	123	1.00	123	1,580	694
9/13	179	0.95	170	182	1.00	182	1,750	876
9/14	167	0.95	159	235	1.00	235	1,909	1,111
9/15	226	0.95	215	190	1.00	190	2,123	1,301
9/16	178	0.95	169	306	1.00	306	2,292	1,607
9/17	181	0.95	172	217	1.00	217	2,464	1,824
9/18	143	0.95	136	228	1.00	228	2,600	2,052
9/19	116	0.95	110	165	1.00	165	2,710	2,217
9/20	100	0.95	95	161	1.00	161	2,805	2,378
9/21	65	0.95	62	81	1.00	81	2,867	2,459
9/22	56	0.95	53	127	1.00	127	2,920	2,586
9/23	53	0.95	50	138	1.00	138	2,971	2,724
9/24	32	0.95	30	142	1.00	142	3,001	2,866
9/25	0	0.95	0	202	1.00	202	3,001	3,068
9/26	0	0.95	0	111	1.00	111	3,001	3,179
9/27	0	0.95	0	39	1.00	39	3,001	3,218
9/28	0	0.94	0	18	1.00	18	3,001	3,236
9/29	0	0.94	0	5	1.00	5	3,001	3,241
9/30	0	0.94	0	2	1.00	2	3,001	3,243
10/1	0	0.91	0	3	1.00	3	3,001	3,246
10/2	0	0.90	0	2	1.00	2	3,001	3,248
10/3	0	0.86	0	1	1.00	1	3,001	3,249
10/4	0	0.74	0	0	1.00	0	3,001	3,249
10/5	0	0.45	0	1	1.00	1	3,001	3,250
10/6	0	0.13	0	0	1.00	0	3,001	3,250

Table 5. Number of tags recovered by location from fall chum salmon tagged in the Tanana and Kantishna Rivers, 2002.

Recapture Location	Number of Tags
Bluff Cabin Slough [a]	28
Delta River [a]	100
Toklat Springs [a, b]	252
Tanana River recovery wheel	71
Toklat River recovery wheels	167
Kantishna River recovery wheel	14
Nenana [c]	7
17 Mile Slough	1
Russian Mission [c]	1
Tanana River near Tolovana River [c]	11
Total	652

[a] Tags recovered from foot surveys of spawning streams.

[b] Include tags deployed from other years.

[c] Tags recovered from subsistence catches.

Table 6. Daily and cumulative catch statistics and Bailey abundance estimates of fall chum salmon in the Tanana River, 2002.

Date	Adjusted (Releases)	Examined For Tags	Recaptures	Abundance	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Standard Error	CV
8/16	2	9						
8/17	8	16						
8/18	10	26						
8/19	15	27						
8/20	15	27						
8/21	15	27						
8/22	19	27						
8/23	34	28						
8/24	57	28						
8/25	96	29						
8/26	122	31						
8/27	151	32						
8/28	174	37						
8/29	200	44						
8/30	209	54	1					
8/31	225	66	1					
9/1	233	88	1					
9/2	238	111	2	8,885	295	17,475	4,383	0.49
9/3	252	149	2	12,600	376	24,824	6,237	0.49
9/4	269	189	2	17,037	473	33,601	8,451	0.50
9/5	286	305	2	29,172	724	57,620	14,514	0.50
9/6	358	409	3	48,927	16,920	80,934	16,330	0.33
9/7	414	536	3	74,106	25,570	122,642	24,763	0.33
9/8	485	709	4	68,870	13,957	123,783	28,017	0.41
9/9	551	857	5	78,793	20,627	136,959	29,677	0.38
9/10	643	1,054	8	75,374	28,856	121,892	23,733	0.31
9/11	894	1,311	11	97,744	44,853	150,635	26,985	0.28
9/12	1,239	1,569	13	138,945	68,943	208,947	35,715	0.26
9/13	1,512	1,875	17	157,584	87,066	228,102	35,978	0.23
9/14	1,693	1,995	22	146,923	88,481	205,365	29,817	0.20
9/15	1,852	2,156	31	124,836	82,560	167,112	21,569	0.17
9/16	1,939	2,296	38	114,202	79,112	149,292	17,903	0.16
9/17	2,016	2,408	45	105,577	75,683	135,471	15,252	0.14
9/18	2,067	2,511	47	108,173	78,175	138,171	15,305	0.14
9/19	2,143	2,570	48	112,442	81,573	143,311	15,749	0.14
9/20	2,220	2,611	49	115,973	84,450	147,496	16,083	0.14
9/21	2,286	2,685	50	120,396	87,984	152,808	16,537	0.14
9/22	2,343	2,769	57	111,898	83,645	140,151	14,415	0.13
9/23	2,379	2,835	60	110,604	83,370	137,838	13,895	0.13
9/24	2,408	2,893	65	105,587	80,594	130,580	12,752	0.12
9/25	2,423	2,956	66	106,937	81,809	132,065	12,820	0.12
9/26	2,452	3,008	68	106,929	82,168	131,690	12,633	0.12
9/27	2,484	3,063	68	110,348	84,790	135,906	13,040	0.12
9/28	2,484	3,107	69	110,334	84,960	135,708	12,946	0.12
9/29	2,484	3,139	70	109,900	84,803	134,997	12,805	0.12
9/30	2,484	3,185	71	109,961	85,022	134,900	12,724	0.12

[a] The number of tags deployed was adjusted by 5% for mortality.

Table 7. Daily and cumulative catch statistics and Bailey abundance estimates of fall chum salmon in the Kantishna River, 2002.

Date	Adjusted (Releases)	Examined For Tags	Recaptures	Abundance	95% Confidence Bounds Lower	95% Confidence Bounds Upper	Standard Error	CV
8/16	8	3	0					
8/17	19	4	0					
8/18	34	4	0					
8/19	43	4	0					
8/20	47	4	0					
8/21	53	6	0					
8/22	67	8	0					
8/23	82	10	0					
8/24	104	15	0					
8/25	117	18	1					
8/26	138	19	1					
8/27	156	31	1					
8/28	177	47	2	2,832	145	5,519	1,371	0.48
8/29	194	59	3	2,910	446	5,374	1,257	0.43
8/30	214	75	3	4,066	597	7,535	1,770	0.44
8/31	239	89	4	4,302	957	7,647	1,707	0.40
9/1	264	123	7	4,092	1,506	6,678	1,319	0.32
9/2	277	140	7	4,882	1,784	7,980	1,581	0.32
9/3	311	168	9	5,256	2,243	8,269	1,537	0.29
9/4	371	203	9	7,568	3,206	11,930	2,225	0.29
9/5	392	258	12	7,810	3,823	11,797	2,034	0.26
9/6	491	308	13	10,837	5,478	16,196	2,734	0.25
9/7	644	345	14	14,855	7,736	21,974	3,632	0.24
9/8	794	397	17	17,556	9,842	25,270	3,936	0.22
9/9	949	452	21	19,541	11,751	27,331	3,974	0.20
9/10	1,146	503	24	23,103	14,445	31,761	4,417	0.19
9/11	1,363	601	26	30,390	19,389	41,391	5,613	0.18
9/12	1,580	728	30	37,155	24,558	49,752	6,427	0.17
9/13	1,750	918	38	41,237	28,732	53,742	6,380	0.15
9/14	1,909	1,173	58	37,986	28,619	47,353	4,779	0.13
9/15	2,123	1,370	65	44,101	33,798	54,404	5,256	0.12
9/16	2,292	1,700	89	43,319	34,657	51,981	4,419	0.10
9/17	2,464	1,932	104	45,361	36,963	53,759	4,285	0.09
9/18	2,600	2,169	113	49,491	40,686	58,296	4,492	0.09
9/19	2,710	2,338	117	53,718	44,313	63,123	4,798	0.09
9/20	2,805	2,506	124	56,257	46,682	65,832	4,885	0.09
9/21	2,867	2,594	131	56,363	47,031	65,695	4,761	0.08
9/22	2,920	2,725	135	58,529	48,976	68,082	4,874	0.08
9/23	2,971	2,871	143	59,255	49,855	68,655	4,796	0.08
9/24	3,001	3,026	156	57,860	49,075	66,645	4,482	0.08
9/25	3,001	3,239	167	57,876	49,379	66,373	4,335	0.07
9/26	3,001	3,360	177	56,665	48,587	64,743	4,122	0.07

[a] The number of tags deployed was adjusted by 5% for mortality.

Table 8. Tanana and Kantishna River abundance estimates using the Bailey model, 1995-2002.

Tanana River

Year	Point Estimate	S.E.	95% Lower Bound	95% Upper bound
1995	268,173	21,597	225,842	310,503
1996	134,563	16,945	101,351	167,775
1997	71,661	11,876	48,384	94,937
1998	62,014	6,556	49,164	74,863
1999	97,843	19,362	59,893	135,792
2000	34,844	4,970	25,104	44,584
2001	96,556	20,955	55,484	137,627
2002	109,961	12,724	85,022	134,900
1995-2001 Mean	109,379			

Kantishna River

Year	Point Estimate	S.E.	95% Lower Bound	95% Upper bound
1999	27,199	3,562	20,218	34,180
2000	21,450	3,031	15,510	27,390
2001	22,992	2,172	18,734	27,250
2002	56,665	4,122	48,587	64,743
1999-2001 Mean	23,880			

Table 9. Estimated fall chum salmon migration rates (km/day) for day and night caught fall chum salmon in the Tanana and Kantishna Rivers, 1995-2002.

Tanana River tagging fish wheel to Tanana River recovery fish wheel (76 km)

	Day		Night		Combined	
Year	km/day	n	km/day	n	km/day	Total - n
1995	-	-	-	-	26	166
1996	-	-	-	-	31	187
1997	-	-	-	-	21	104
1998	29	49	31	30	30	79
1999	29	8	16	14	23	22
2000	25	25	20	20	23	45
2001	24	10	49	7	37	17
2002	28	22	29	47	29	69
mean	27	23	29	24	27	86

Kantishna River tagging fish wheel to Toklat River recovery fish wheels (114 km)

	Day		Night		Combined	
Year	km/day	n	km/day	n	km/day	Total - n
1999	20	26	22	28	21	54
2000	25	24	29	9	27	33
2001	25	52	28	37	27	89
2002	24	84	27	81	26	165
mean	24	47	27	39	25	59

Kantishna River tagging fish wheel to upper Kantishna River recovery fish wheel (139 km)

	Day		Night		Combined	
Year	km/day	n	km/day	n	km/day	Total - n
2000	26	10	27	1	27	11
2001	31	2	28	3	30	5
2002	21	10	21	4	21	14
mean	26	6	25	3	28	10

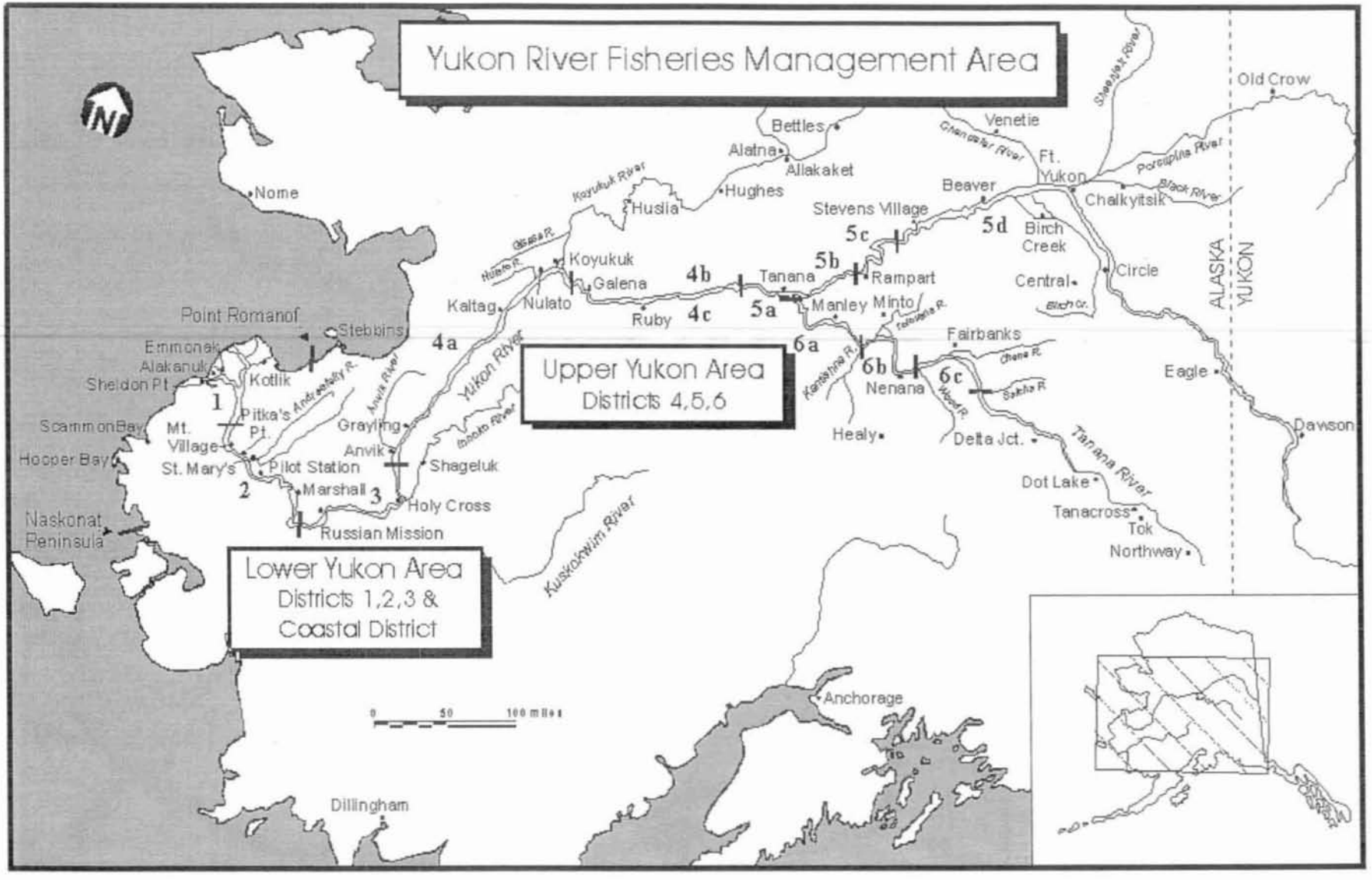


Figure 1. Fisheries management districts and subdistricts on theYukon and Tanana River drainages.

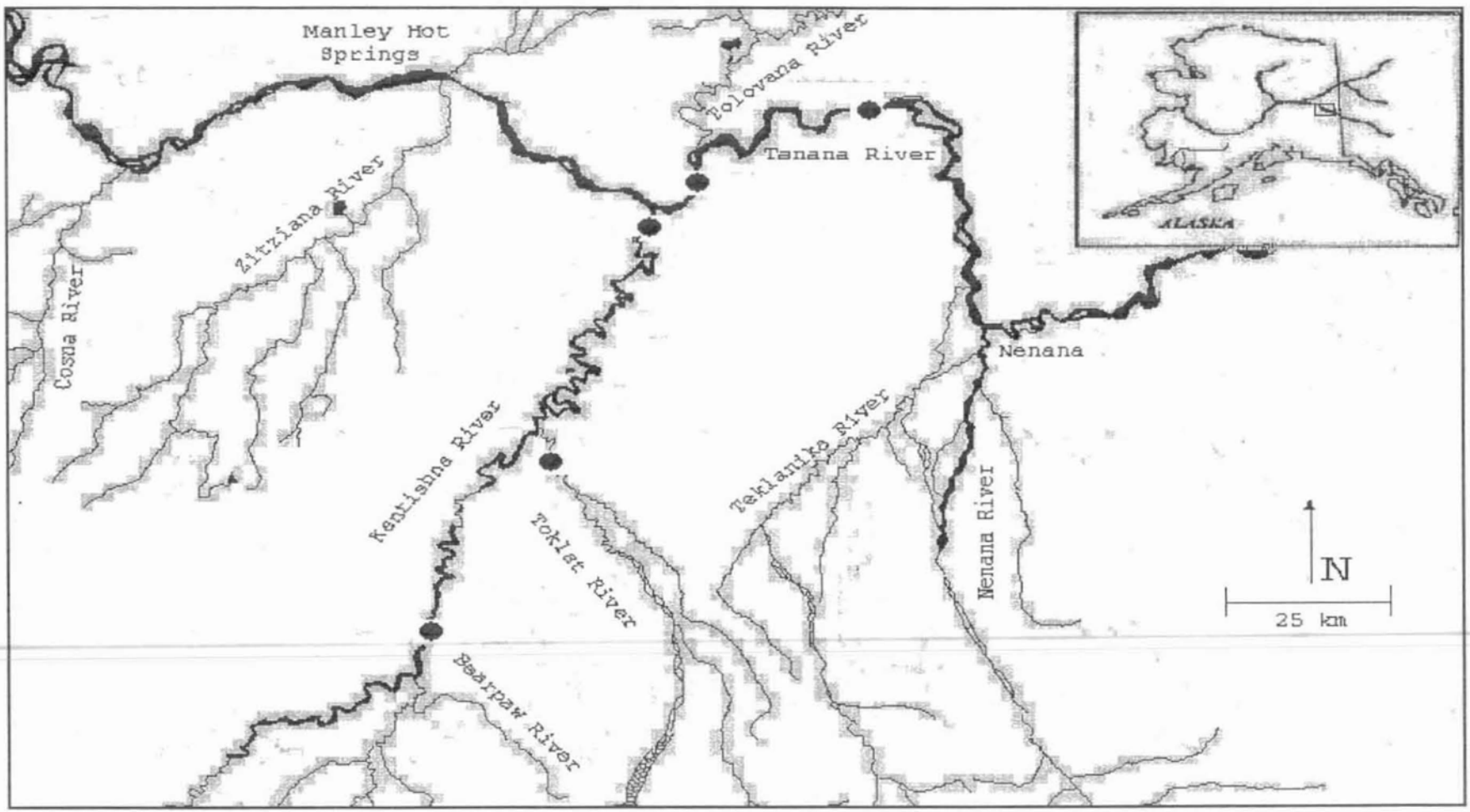


Figure 2. Location of tag deployment and recovery fish wheels (black circle) used in the Tanana River fall chum salmon tagging project.

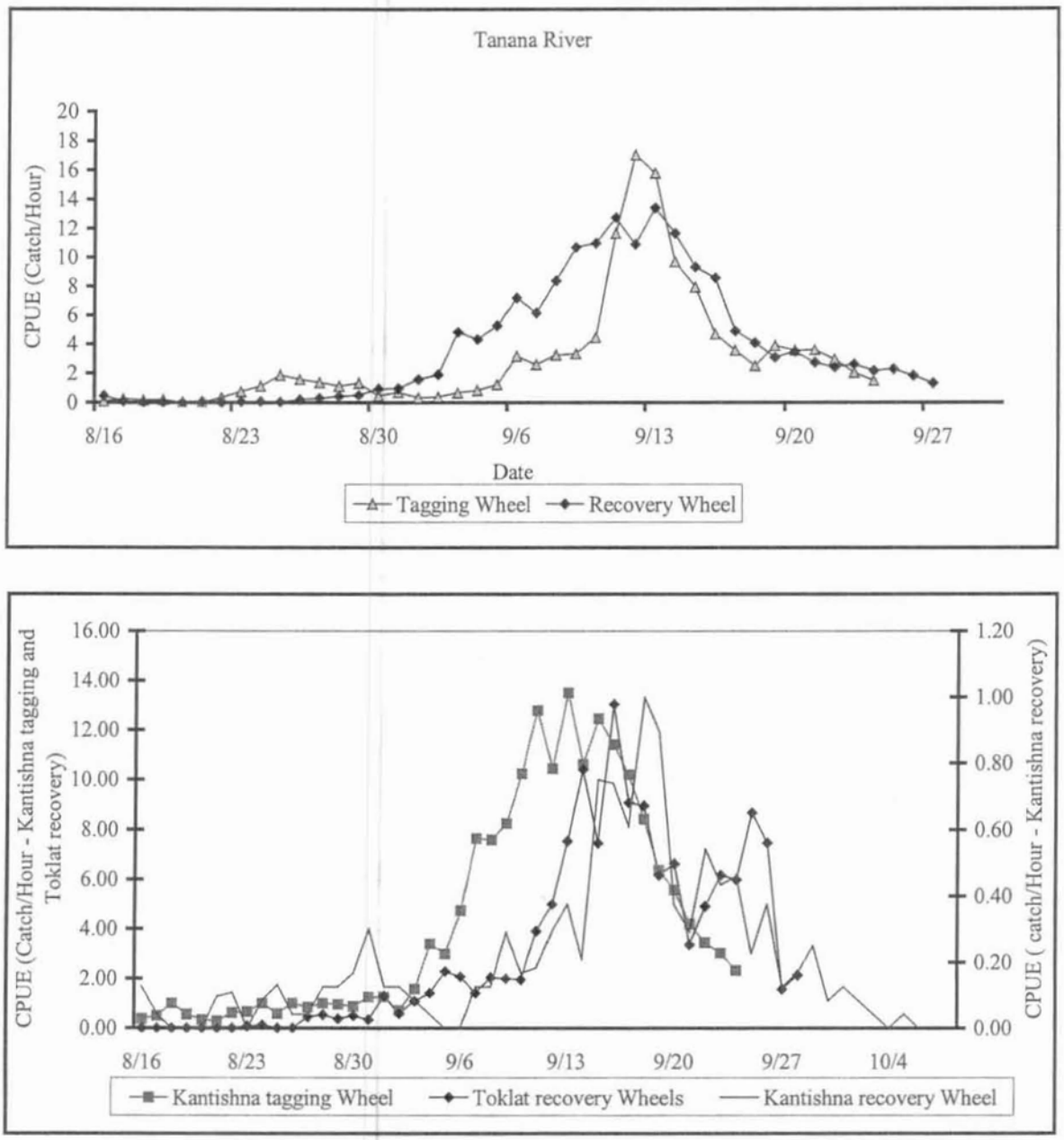


Figure 3. Daily fall chum salmon CPUE at the Tanana River tagging and recovery fish wheels (above), and CPUE at the Kantishna River tagging and recovery fish wheels and the recovery fish wheels on the Toklat River (below), 2002.

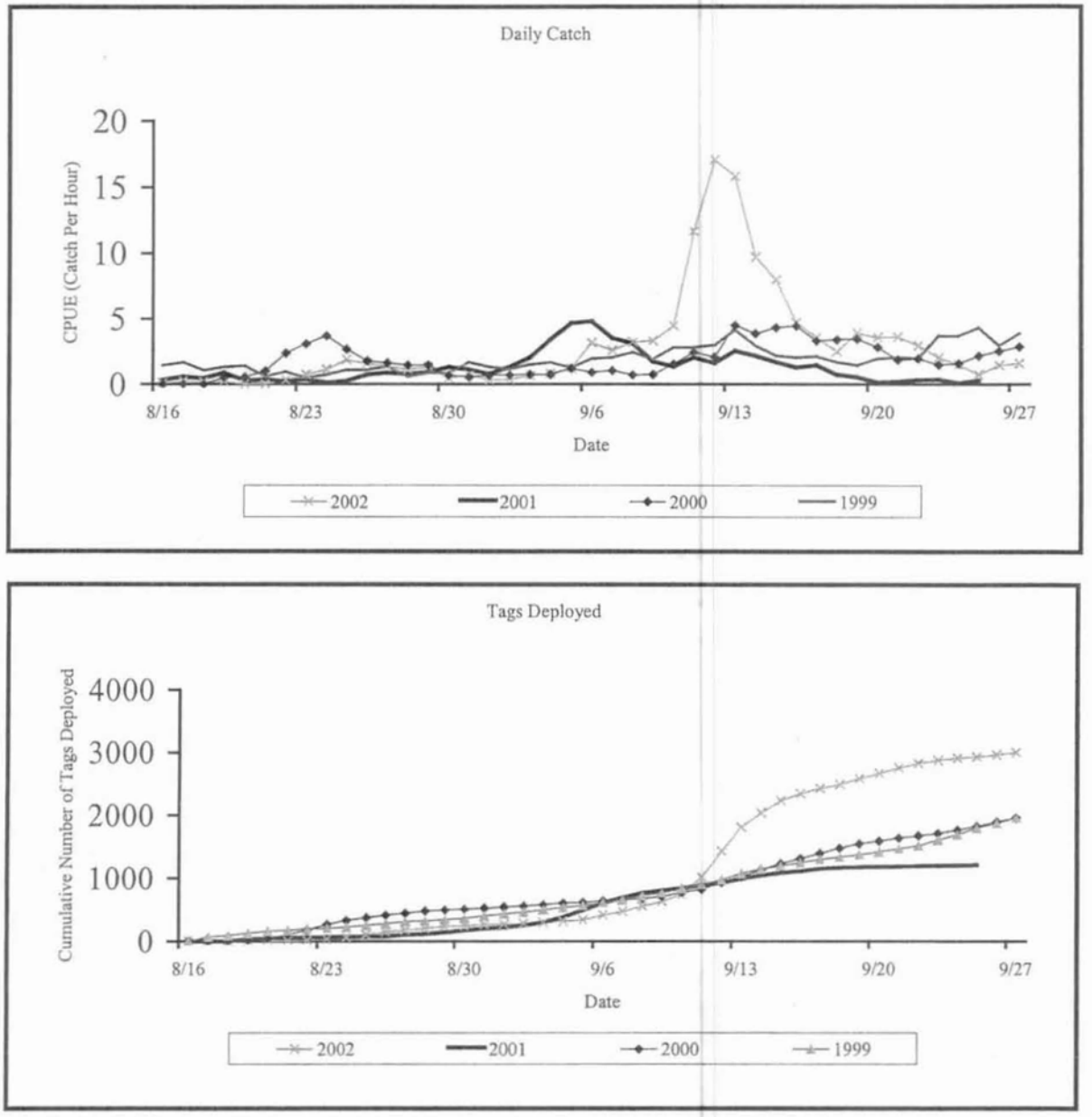


Figure 4. Daily fall chum salmon CPUE at the Tanana River tag deployment fish wheel (above) and the cumulative number of tags deployed at the same location (below), 1999-2002.

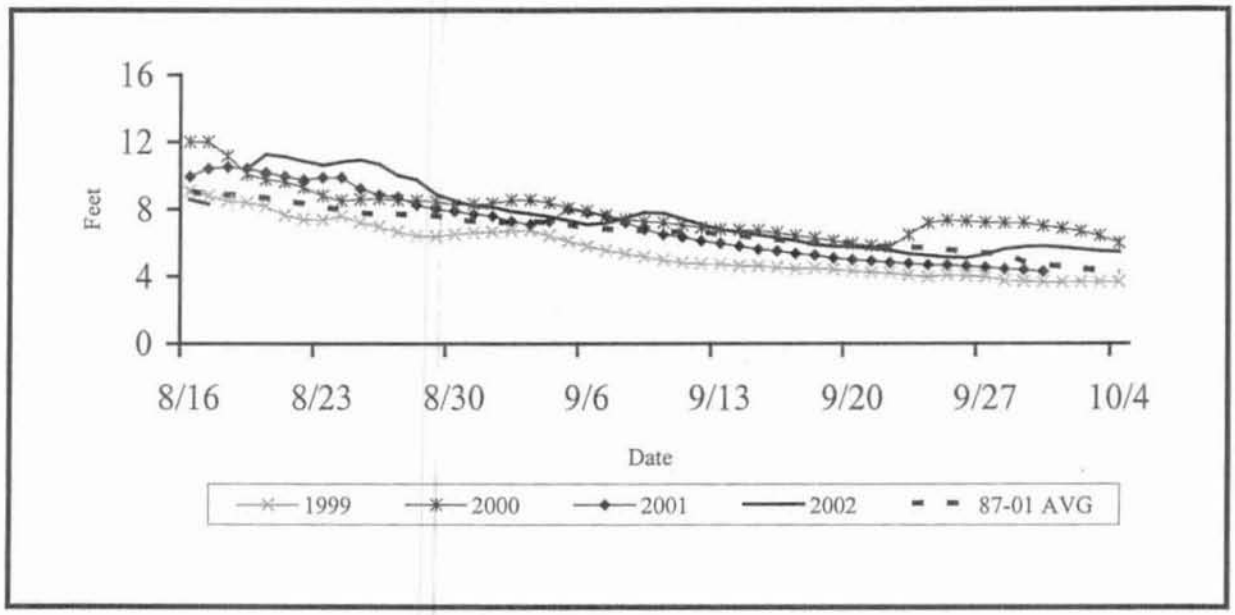
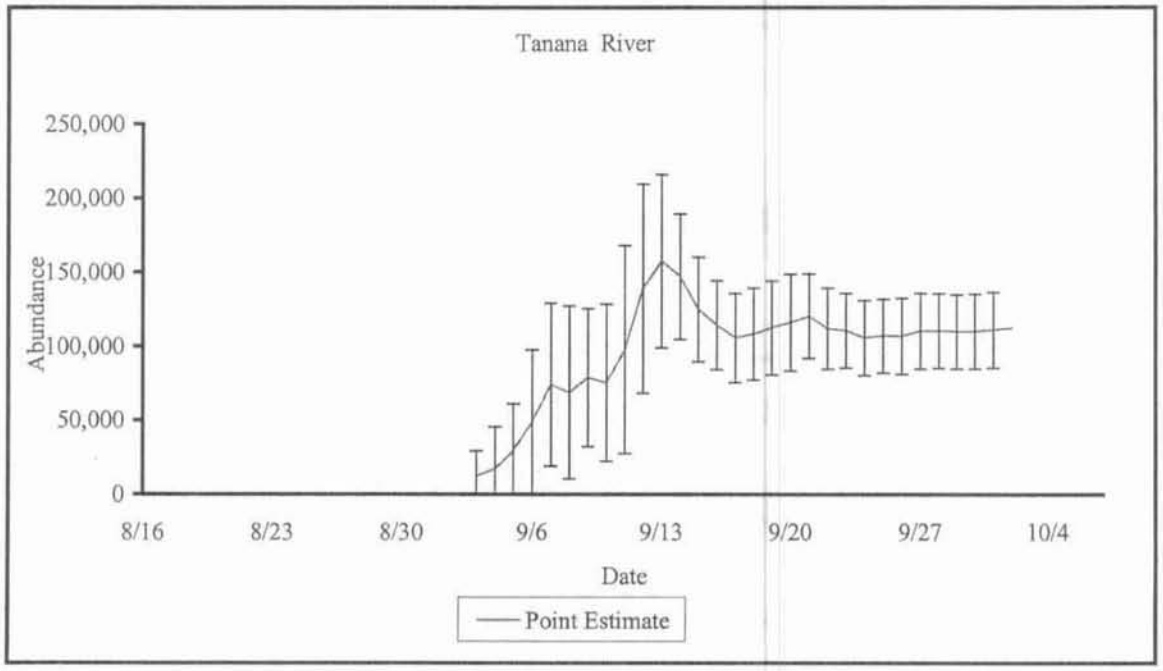


Figure 5. Daily water levels on the Tanana River as measured by a United States Geological Survey gauge located near Nenana, 1999-2002.



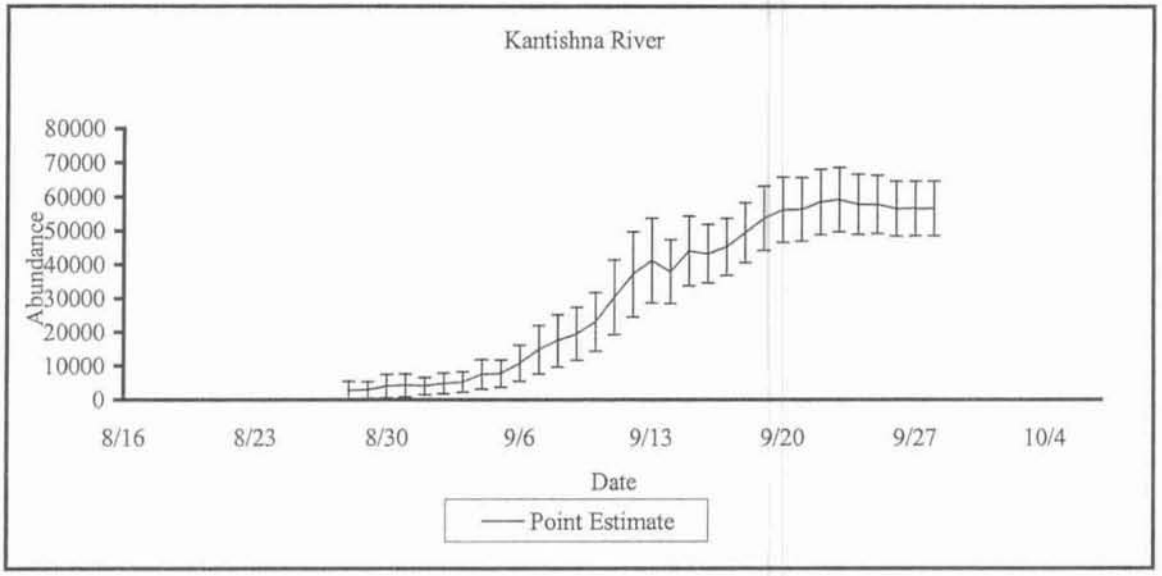


Figure 6. Inseason abundance estimates and associated confidence bounds using the Bailey model for fall chum salmon tagged on the Tanana River (above) and Kantishna River (below), 2002.

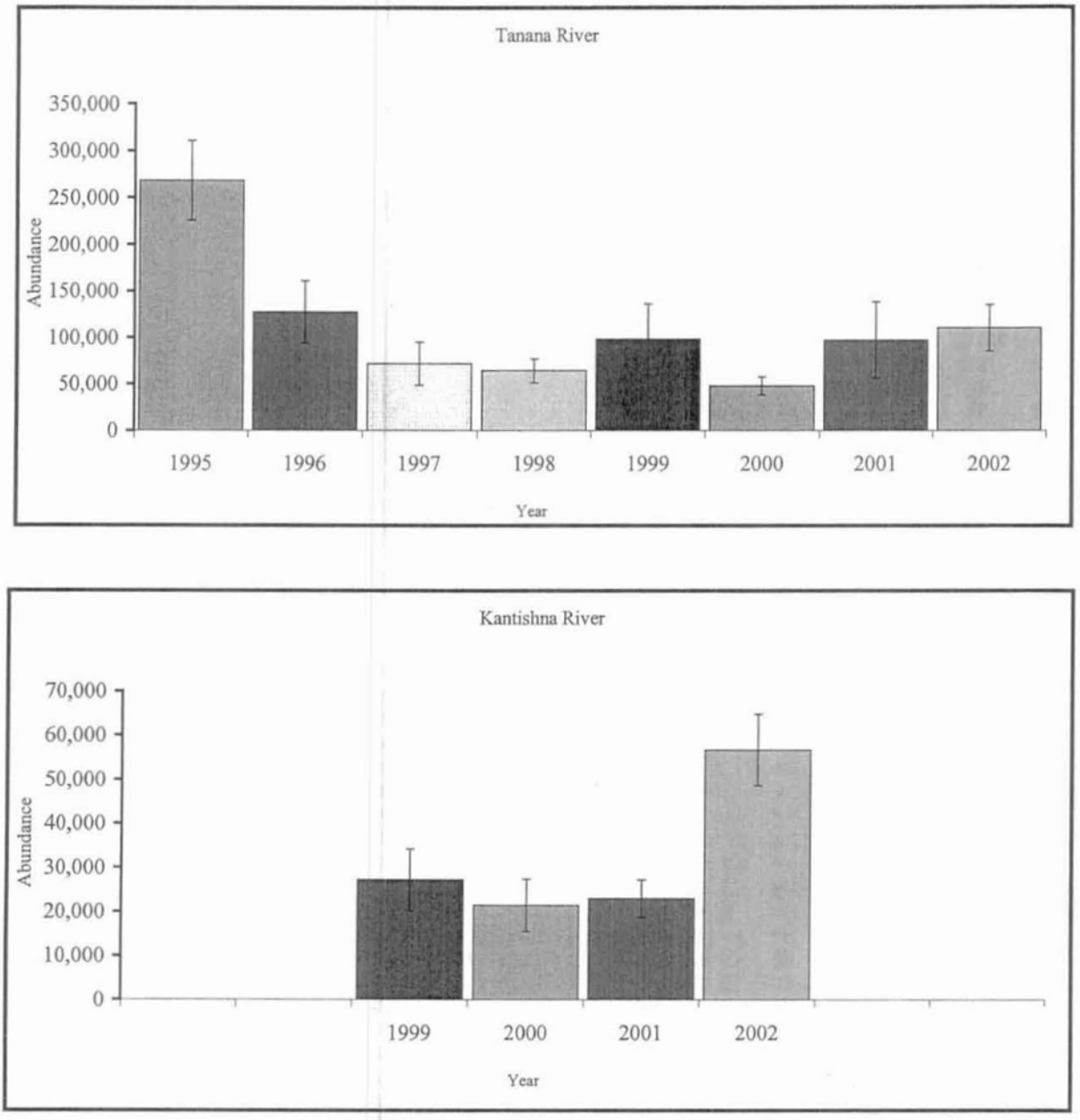


Figure 7. Abundance estimates and 95% confidence bounds for fall chum salmon on the Tanana River, 1995-2002 (above) and for the Kantishna River, (below) 1999-2002.

Appendix A. Daily effort and catch of fall chum salmon in the Tanana River tagging fish wheel, 2002.

		Tagged				Not Tagged				Total			
Date	Hours Fished	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative
8/16	24	1	1	2	2	0	0	0	0	1	1	2	2
8/17	24	0	6	6	8	0	0	0	0	0	6	6	8
8/18	24	2	1	3	11	1	0	1	1	3	1	4	12
8/19	3	3	2	5	16	0	0	0	1	3	2	5	17
8/20	0	0	0	0	16	0	0	0	1	0	0	0	17
8/21	12	0	0	0	16	0	0	0	1	0	0	0	17
8/22	24	1	3	4	20	0	0	0	1	1	3	4	21
8/23	24	11	5	16	36	1	1	2	3	12	6	18	39
8/24	24	9	15	24	60	1	2	3	6	10	17	27	66
8/25	24	23	18	41	101	2	2	4	10	25	20	45	111
8/26	24	18	9	27	128	1	10	11	21	19	19	38	149
8/27	24	16	15	31	159	0	2	2	23	16	17	33	182
8/28	24	12	12	24	183	2	1	3	26	14	13	27	209
8/29	24	16	11	27	210	1	4	5	31	17	15	32	241
8/30	24	7	3	10	220	0	1	1	32	7	4	11	252
8/31	24	8	9	17	237	0	0	0	32	8	9	17	269
9/1	24	4	4	8	245	0	0	0	32	4	4	8	277
9/2	24	3	3	6	251	1	2	3	35	4	5	9	286
9/3	24	10	4	14	265	1	1	2	37	11	5	16	302
9/4	18	8	10	18	283	1	1	2	39	9	11	20	322
9/5	24	12	6	18	301	1	3	4	43	13	9	22	344
9/6	24	35	41	76	377	0	0	0	43	35	41	76	420
9/7	24	35	24	59	436	2	1	3	46	37	25	62	482
9/8	24	34	40	74	510	1	3	4	50	35	43	78	560
9/9	24	32	38	70	580	6	4	10	60	38	42	80	640
9/10	24	44	53	97	677	4	6	10	70	48	59	107	747
9/11	24	134	130	264	941	3	13	16	86	137	143	280	1,027
9/12	24	188	175	363	1,304	18	28	46	132	206	203	409	1,436
9/13	24	155	133	288	1,592	37	54	91	223	192	187	379	1,815
9/14	24	96	94	190	1,782	24	19	43	266	120	113	233	2,048
9/15	24	74	93	167	1,949	12	12	24	290	86	105	191	2,239
9/16	24	33	59	92	2,041	11	10	21	311	44	69	113	2,352
9/17	24	27	54	81	2,122	2	3	5	316	29	57	86	2,438
9/18	24	22	32	54	2,176	3	3	6	322	25	35	60	2,498
9/19	24	26	54	80	2,256	3	11	14	336	29	65	94	2,592
9/20	24	30	51	81	2,337	2	3	5	341	32	54	86	2,678
9/21	24	31	38	69	2,406	6	12	18	359	37	50	87	2,765
9/22	24	26	34	60	2,466	6	5	11	370	32	39	71	2,836
9/23	24	10	28	38	2,504	3	8	11	381	13	36	49	2,885
9/24	24	8	23	31	2,535	1	4	5	386	9	27	36	2,921
9/25	24	5	11	16	2,551	1	1	2	388	6	12	18	2,939
9/26	24	8	22	30	2,581	1	4	5	393	9	26	35	2,974
9/27	24	6	29	35	2,616	1	2	3	396	7	31	38	3,012
Total		1,223	1,393	2,616		160	236	396		1,383	1,629	3,012	

Appendix B. Daily effort and catch of fall chum salmon at the Kantishna River tagging fish wheel, 2002.

		Tagged				Not Tagged				Total			
Date	Hours Fished	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative
8/16	24	6	2	8	8	1	0	1	1	7	2	9	9
8/17	24	5	7	12	20	0	0	0	1	5	7	12	21
8/18	18	12	4	16	36	1	1	2	3	13	5	18	39
8/19	18	7	2	9	45	1	0	1	4	8	2	10	49
8/20	12	3	1	4	49	0	0	0	4	3	1	4	53
8/21	24	4	3	7	56	0	0	0	4	4	3	7	60
8/22	24	8	6	14	70	0	1	1	5	8	7	15	75
8/23	24	10	6	16	86	0	0	0	5	10	6	16	91
8/24	24	16	7	23	109	0	1	1	6	16	8	24	115
8/25	24	11	3	14	123	0	0	0	6	11	3	14	129
8/26	24	16	6	22	145	0	2	2	8	16	8	24	153
8/27	24	16	3	19	164	0	1	1	9	16	4	20	173
8/28	24	14	8	22	186	2	0	2	11	16	8	24	197
8/29	24	15	3	18	204	2	3	5	16	17	6	23	220
8/30	24	15	6	21	225	0	0	0	16	15	6	21	241
8/31	24	14	13	27	252	2	1	3	19	16	14	30	271
9/1	24	18	8	26	278	2	2	4	23	20	10	30	301
9/2	24	10	4	14	292	0	3	3	26	10	7	17	318
9/3	24	29	6	35	327	1	2	3	29	30	8	38	356
9/4	20	42	22	64	391	1	3	4	33	43	25	68	424
9/5	8	16	6	22	413	0	2	2	35	16	8	24	448
9/6	24	74	30	104	517	3	7	10	45	77	37	114	562
9/7	23	95	66	161	678	13	2	15	60	108	68	176	738
9/8	24	105	53	158	836	17	7	24	84	122	60	182	920
9/9	24	92	71	163	999	25	10	35	119	117	81	198	1,118
9/10	24	126	81	207	1,206	23	16	39	158	149	97	246	1,364
9/11	24	151	78	229	1,435	21	57	78	236	172	135	307	1,671
9/12	24	138	90	228	1,663	17	6	23	259	155	96	251	1,922
9/13	24	121	58	179	1,842	86	59	145	404	207	117	324	2,246
9/14	24	104	63	167	2,009	44	44	88	492	148	107	255	2,501
9/15	24	139	87	226	2,235	45	28	73	565	184	115	299	2,800
9/16	24	111	67	178	2,413	49	47	96	661	160	114	274	3,074
9/17	24	91	90	181	2,594	32	32	64	725	123	122	245	3,319
9/18	24	67	76	143	2,737	23	36	59	784	90	112	202	3,521
9/19	24	58	58	116	2,853	22	15	37	821	80	73	153	3,674
9/20	24	58	42	100	2,953	14	20	34	855	72	62	134	3,808
9/21	24	30	35	65	3,018	18	18	36	891	48	53	101	3,909
9/22	24	25	31	56	3,074	15	12	27	918	40	43	83	3,992
9/23	24	19	34	53	3,127	8	12	20	938	27	46	73	4,065
9/24	24	8	24	32	3,159	8	16	24	962	16	40	56	4,121
Total		1,899	1,260	3,159		496	466	962		2,395	1,726	4,121	

Appendix C. Daily effort and catch of tagged and untagged fall chum salmon in the Tanana River recovery fish wheel, 2002.

		Tagged				Not Tagged				Total			
Date	Hours Fished	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative
8/16	22	0	0	0	0	6	3	9	9	6	3	9	9
8/17	18	0	0	0	0	4	3	7	16	4	3	7	16
8/18	22	0	0	0	0	5	5	10	26	5	5	10	26
8/19	10	0	0	0	0	0	1	1	27	0	1	1	27
8/20	0	0	0	0	0	0	0	0	27	0	0	0	27
8/21	0	0	0	0	0	0	0	0	27	0	0	0	27
8/22	0	0	0	0	0	0	0	0	27	0	0	0	27
8/23	16	0	0	0	0	0	1	1	28	0	1	1	28
8/24	9	0	0	0	0	0	0	0	28	0	0	0	28
8/25	15	0	0	0	0	1	0	1	29	1	0	1	29
8/26	24	0	0	0	0	1	1	2	31	1	1	2	31
8/27	24	0	0	0	0	0	1	1	32	0	1	1	32
8/28	24	0	0	0	0	3	2	5	37	3	2	5	37
8/29	24	0	0	0	0	4	3	7	44	4	3	7	44
8/30	24	0	1	1	1	9	0	9	53	9	1	10	54
8/31	24	0	0	0	1	6	6	12	65	6	6	12	66
9/1	24	0	0	0	1	11	11	22	87	11	11	22	88
9/2	24	1	0	1	2	13	9	22	109	14	9	23	111
9/3	24	0	0	0	2	20	18	38	147	20	18	38	149
9/4	21	0	0	0	2	22	18	40	187	22	18	40	189
9/5	24	0	0	0	2	67	49	116	303	67	49	116	305
9/6	24	0	1	1	3	52	51	103	406	52	52	104	409
9/7	24	0	0	0	3	70	57	127	533	70	57	127	536
9/8	24	1	0	1	4	85	87	172	705	86	87	173	709
9/9	24	0	1	1	5	72	75	147	852	72	76	148	857
9/10	24	2	1	3	8	98	96	194	1,046	100	97	197	1,054
9/11	24	3	0	3	11	137	117	254	1,300	140	117	257	1,311
9/12	24	0	2	2	13	155	101	256	1,556	155	103	258	1,569
9/13	24	2	2	4	17	167	135	302	1,858	169	137	306	1,875
9/14	11	2	3	5	22	57	58	115	1,973	59	61	120	1,995
9/15	12	5	4	9	31	78	74	152	2,125	83	78	161	2,156
9/16	12	3	4	7	38	77	56	133	2,258	80	60	140	2,296
9/17	12	5	2	7	45	47	58	105	2,363	52	60	112	2,408
9/18	12	1	1	2	47	50	51	101	2,464	51	52	103	2,511
9/19	12	0	1	1	48	23	35	58	2,522	23	36	59	2,570
9/20	10	0	1	1	49	16	24	40	2,562	16	25	41	2,611
9/21	24	0	1	1	50	25	48	73	2,635	25	49	74	2,685
9/22	24	2	5	7	57	34	43	77	2,712	36	48	84	2,769
9/23	24	0	3	3	60	29	34	63	2,775	29	37	66	2,835
9/24	24	2	3	5	65	19	34	53	2,828	21	37	58	2,893
9/25	24	0	1	1	66	30	32	62	2,890	30	33	63	2,956
9/26	24	0	2	2	68	20	30	50	2,940	20	32	52	3,008
9/27	24	0	0	0	68	19	36	55	2,995	19	36	55	3,063
9/28	24	0	1	1	69	17	26	43	3,038	17	27	44	3,107
9/29	24	0	1	1	70	14	17	31	3,069	14	18	32	3,139
9/30	24	0	1	1	71	10	35	45	3,114	10	36	46	3,185
10/1	24	0	0	0	71	7	20	27	3,141	7	20	27	3,212
10/2	29	0	0	0	71	9	21	30	3,171	9	21	30	3,242
10/3	19	0	0	0	71	5	11	16	3,187	5	11	16	3,258
10/4	6	0	0	0	71	1	3	4	3,191	1	3	4	3,262
Total		29	42	71		1595	1596	3191		1,624	1,638	3,262	

Appendix D. Daily effort and catch of tagged and untagged fall chum salmon in the Toklat River recovery fish wheels (both wheels combined), 2002.

		Tagged				Not Tagged				Total			
Date	Hours Fished	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative
8/16	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17	0	0	0	0	0	0	0	0	0	0	0	0	0
8/18	0	0	0	0	0	0	0	0	0	0	0	0	0
8/19	0	0	0	0	0	0	0	0	0	0	0	0	0
8/20	0	0	0	0	0	0	0	0	0	0	0	0	0
8/21	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22	0	0	0	0	0	0	0	0	0	0	0	0	0
8/23	12	0	0	0	0	1	1	2	2	1	1	2	2
8/24	12	0	0	0	0	1	2	3	5	1	2	3	5
8/25	12	0	0	0	0	0	0	0	5	0	0	0	5
8/26	18	0	0	0	0	0	0	0	5	0	0	0	5
8/27	20	0	0	0	0	6	5	11	16	6	5	11	16
8/28	24	1	0	1	1	2	10	12	28	3	10	13	29
8/29	24	1	0	1	2	5	3	8	36	6	3	9	38
8/30	24	0	0	0	2	5	7	12	48	5	7	12	50
8/31	24	1	0	1	3	4	3	7	55	5	3	8	58
9/1	24	2	0	2	5	23	6	29	84	25	6	31	89
9/2	24	0	0	0	5	8	6	14	98	8	6	14	103
9/3	24	1	1	2	7	9	15	24	122	10	16	26	129
9/4	24	0	0	0	7	17	17	34	156	17	17	34	163
9/5	24	2	1	3	10	30	22	52	208	32	23	55	218
9/6	24	0	1	1	11	22	27	49	257	22	28	50	268
9/7	24	1	0	1	12	12	21	33	290	13	21	34	302
9/8	24	2	0	2	14	27	20	47	337	29	20	49	351
9/9	24	3	0	3	17	20	25	45	382	23	25	48	399
9/10	24	3	0	3	20	30	14	44	426	33	14	47	446
9/11	24	1	1	2	22	53	39	92	518	54	40	94	540
9/12	24	2	2	4	26	51	65	116	634	53	67	120	660
9/13	24	6	1	7	33	94	80	174	808	100	81	181	841
9/14	24	13	7	20	53	115	115	230	1,038	128	122	250	1,091
9/15	24	2	3	5	58	94	80	174	1,212	96	83	179	1,270
9/16	24	16	8	24	82	135	154	289	1,501	151	162	313	1,583
9/17	24	10	5	15	97	81	122	203	1,704	91	127	218	1,801
9/18	24	9	0	9	106	108	98	206	1,910	117	98	215	2,016
9/19	24	1	2	3	109	73	72	145	2,055	74	74	148	2,164
9/20	24	5	2	7	116	70	82	152	2,207	75	84	159	2,323
9/21	24	5	2	7	123	30	44	74	2,281	35	46	81	2,404
9/22	24	0	3	3	126	39	76	115	2,396	39	79	118	2,522
9/23	23	3	3	6	132	57	73	130	2,526	60	76	136	2,658
9/24	24	7	5	12	144	55	77	132	2,658	62	82	144	2,802
9/25	24	5	6	11	155	65	132	197	2,855	70	138	208	3,010
9/26	15	5	5	10	165	30	72	102	2,957	35	77	112	3,122
9/27	12	0	2	2	167	8	28	36	2,993	8	30	38	3,160
9/28	4	0	0	0	167	6	9	15	3,008	6	9	15	3,175
Total		107	60	167		1,386	1,622	3,008		1,493	1,682	3,175	

Appendix E. Daily effort and catch of tagged and untagged fall chum salmon in the Kantishna River recovery fish wheel, 2002.

		Tagged				Not Tagged				Total			
Date	Hours Fished	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative	Males	Females	Total	Cumulative
8/16	24	0	0	0	0	3	0	3	3	3	0	3	3
8/17	24	0	0	0	0	0	1	1	4	0	1	1	4
8/18	24	0	0	0	0	0	0	0	4	0	0	0	4
8/19	24	0	0	0	0	0	0	0	4	0	0	0	4
8/20	24	0	0	0	0	0	0	0	4	0	0	0	4
8/21	21	0	0	0	0	1	1	2	6	1	1	2	6
8/22	19	0	0	0	0	0	2	2	8	0	2	2	8
8/23	24	0	0	0	0	0	0	0	8	0	0	0	8
8/24	24	0	0	0	0	1	1	2	10	1	1	2	10
8/25	23	1	0	1	1	0	2	2	12	1	2	3	13
8/26	24	0	0	0	1	1	0	1	13	1	0	1	14
8/27	24	0	0	0	1	1	0	1	14	1	0	1	15
8/28	24	0	0	0	1	1	2	3	17	1	2	3	18
8/29	24	0	0	0	1	1	2	3	20	1	2	3	21
8/30	24	0	0	0	1	2	2	4	24	2	2	4	25
8/31	20	0	0	0	1	3	3	6	30	3	3	6	31
9/1	24	0	1	1	2	2	0	2	32	2	1	3	34
9/2	24	0	0	0	2	2	1	3	35	2	1	3	37
9/3	24	0	0	0	2	1	1	2	37	1	1	2	39
9/4	24	0	0	0	2	1	0	1	38	1	0	1	40
9/5	24	0	0	0	2	0	0	0	38	0	0	0	40
9/6	24	0	0	0	2	0	0	0	38	0	0	0	40
9/7	24	0	0	0	2	2	1	3	41	2	1	3	43
9/8	24	1	0	1	3	1	1	2	43	2	1	3	46
9/9	24	1	0	1	4	3	3	6	49	4	3	7	53
9/10	24	0	0	0	4	2	2	4	53	2	2	4	57
9/11	22	0	0	0	4	1	3	4	57	1	3	4	61
9/12	24	0	0	0	4	4	3	7	64	4	3	7	68
9/13	24	1	0	1	5	2	6	8	72	3	6	9	77
9/14	24	0	0	0	5	4	1	5	77	4	1	5	82
9/15	24	2	0	2	7	9	7	16	93	11	7	18	100
9/16	23	0	0	0	7	9	8	17	110	9	8	17	117
9/17	23	0	0	0	7	6	8	14	124	6	8	14	131
9/18	22	0	0	0	7	10	12	22	146	10	12	22	153
9/19	24	0	1	1	8	14	6	20	166	14	7	21	174
9/20	24	0	0	0	8	4	5	9	175	4	5	9	183
9/21	24	0	0	0	8	4	3	7	182	4	3	7	190
9/22	24	1	0	1	9	7	5	12	194	8	5	13	203
9/23	23	2	0	2	11	4	4	8	202	6	4	10	213
9/24	24	1	0	1	12	4	6	10	212	5	6	11	224
9/25	22	0	0	0	12	2	3	5	217	2	3	5	229
9/26	24	0	0	0	12	7	2	9	226	7	2	9	238
9/27	24	0	0	0	12	0	3	3	229	0	3	3	241
9/28	24	0	1	1	13	2	1	3	232	2	2	4	245
9/29	24	0	1	1	14	1	4	5	237	1	5	6	251
9/30	24	0	0	0	14	1	1	2	239	1	1	2	253
10/1	24	0	0	0	14	1	2	3	242	1	2	3	256
10/2	24	0	0	0	14	1	1	2	244	1	1	2	258
10/3	24	0	0	0	14	1	0	1	245	1	0	1	259
10/4	24	0	0	0	14	0	0	0	245	0	0	0	259
10/5	24	0	0	0	14	0	1	1	246	0	1	1	260
10/6	18	0	0	0	14	0	0	0	246	0	0	0	260
Total		10	4	14		126	120	246		136	124	260	

Appendix F. Climatological and hydrological observations collected at the Tanana River, 2002.

Date	Precipitation (code)a	Cloud Cover (code)b	Water Temp. (C°)	Water Level (cm)	Water velocity (m/sec)	Air Temp. (C°)	Wind
			Surface	± 24 h Change			Azmuth and speed (mph)
16-Aug							
17-Aug	A	4	10.3		1.41	11.6	W - 15-20
18-Aug	A	4	10.3			9.8	
19-Aug	A	3	9.7			10.2	
20-Aug	G	2	9.7			10.7	NE - 15-20
21-Aug	A	3	9.6			11.2	
22-Aug	A	3	9.6		1.31	10.4	
23-Aug	A	3	9.7		1.58	11.1	
24-Aug	A	2	9.6		1.69	16.1	E- 0-5
25-Aug	E	2	9.8		1.30	15.7	calm
26-Aug	G	2	9.5		1.51	15.1	calm
27-Aug	G	2	9.0		1.66	18.9	
28-Aug	G	3	8.7	3.5	1.76	15.6	NW -7-10
29-Aug	A	3	8.4	9.5	1.92	14.2	
30-Aug	G	3	11.1	12	1.73	16.4	NE 0-5
31-Aug	A	3	10.9	3	2.08	14.4	W- 0-5
01-Sep	A	3	11.0	4	1.76	15.1	W - 8-10
02-Sep	G	2	10.4	3	1.97	14.4	E - 10-15
03-Sep	G	3	10.3	4	1.58	14.4	E - 5-10
04-Sep	A	4	9.8	2	1.94	12.1	E - 3-5
05-Sep	G	3	10.1	5		10.6	
06-Sep	A	4	10.2	5	1.97	12.3	
07-Sep	A	3	10.2	0	2.01	10.6	
08-Sep	A	4	9.2	-8	2.18	11.0	
09-Sep	A	3	8.7	-9	1.95	7.3	SW - 10-12
10-Sep	G	3	8.6	2	1.87	9.0	SW - 5-10
11-Sep	G	4	8.6	5	1.89	9.3	E - 0-5
12-Sep	A	4	8.6	10	1.66	7.9	S - 5-10
13-Sep	A	4	6.4	10	1.77	13.8	S - 5-10
14-Sep	A	2	6.4		1.73	15.7	SE - 10-15
15-Sep	G	4	6.4	6	1.64	11.9	NW - 5-10
16-Sep	G	3	7.8	6	1.47	11.7	W - 0-5
17-Sep	G	3	7.9	6		11.2	NW - 0-5
18-Sep	A	3	7.9	5		11.3	NW - 10-15
19-Sep	G	4	6.9	5	1.42	4.3	NW - 15-20
20-Sep	G	1	6.6	-3	1.81	5.1	
21-Sep	A	1	5.9	-8	1.61	4.6	E - 0-5
22-Sep	G	1	5.1	4	1.37	12.2	NE - 15-20
23-Sep	G	1	4.8	7	1.29	12.2	NE - 0-5
24-Sep	A	4	4.6	3	1.38	11.7	E - 0-5
25-Sep	G	1	5.0	5	1.39	11.9	E - 5-10
26-Sep	A	4	5.0	2		7.1	E - 0-5
27-Sep	G	2	5.2	-5		8.4	
28-Sep	A	4	5.5	-10		9.9	SW - 5-10

A = None, B = Intermittent rain, C = Continuous rain, D = snow and rain mixed, E = light snowfall, F = Continuous snowfall, G = Thunderstorm, w/or w/o precipita
b Cloudcover code: 1 = Clear and visibility unlimited, 2 = partly cloudy, (< 50% cover); 3 = Broken (50-90%),
4 = Overcast (100%), 5 = Fog or thick haze or smoke.